9. COMPARISON OF MEASUREMENTS WITH MODELS

Predictions of signal strength for the Appleton GWEN site were generated using the Institute for Telecommunication Sciences medium frequency propagation models. These models are described by DeMinco [2] and by Haakinson, Rothschild, & Bedford. [3]. Model inputs include transmitter location, frequency, field strength at a reference distance, time of day, and ground conductivity.

Predictions of field strength versus distance were not developed along each of the routes. This is because the complicated routes and irregularities in terrain and ground conductivity would make a comparison between predicted and measured field strengths quite tedious, although in principle such a comparison could be made by making propagation predictions at numerous points along each route. Instead, measured results were compared against the signal strength contours of a coverage plot.

Figure 16 is a signal coverage plot for the Appleton GWEN site during daytime hours, when there is no significant skywave propagation. The boundaries between the five concentric regions in the plot are contours of groundwave field strength corresponding to 37.5, 50.0, 60.0, and 70.0 dBµV/m. The U.S. Coast Guard specifies a minimum field strength of 37.5 dBµV/m for DGPS signal coverage.

The plot was generated using a smooth earth propagation model, which neglects irregular terrain effects but takes into account varying ground conductivity using a conductivity database. The irregular terrain model was not used to generate this plot because terrain effects are generally not expected to be significant at this frequency (300 kHz) and because the irregular terrain model is not numerically stable beyond approximately 250 km, whereas the signal coverage and measured data extend to considerably greater distances. However, a signal coverage plot to distances of 250 km from the transmitter was generated using the irregular terrain model, and is not significantly different from that using the smooth earth model.

Comparisons of the signal coverage plot to the measured data indicate that for the route between Appleton and Spokane, the model and measurements are in close agreement. However, for the other routes, which were driven in hilly or mountainous terrain, the measured field strengths are generally less than those predicted by the model. For example, at Bellingham the difference between the measured and predicted field strengths is greater than 10 dB.

The fact that the irregular terrain and smooth earth models make similar predictions suggests that the larger discrepancies between the model and measurements are not due to irregular terrain effects, but are presumably due to inadequacies in the conductivity database, which is quite sparse at some geographic locations. In mountainous terrain, the ground conductivities are typically poor, and this may not be fully represented in the database.

To further investigate this possibility, the propagation model was used in a mode that does not access the conductivity database, but in which the ground conductivity is entered manually. For example, the values of ground conductivity in the database at the geographic locations corresponding to Spokane and Bellingham are both 0.004 S/m, which is a typical value of conductivity for average ground. Using this value of conductivity, the propagation model predicts that the field strength at Spokane (350 km from Appleton) is 43 dBµV/m, in good agreement with the measured data.

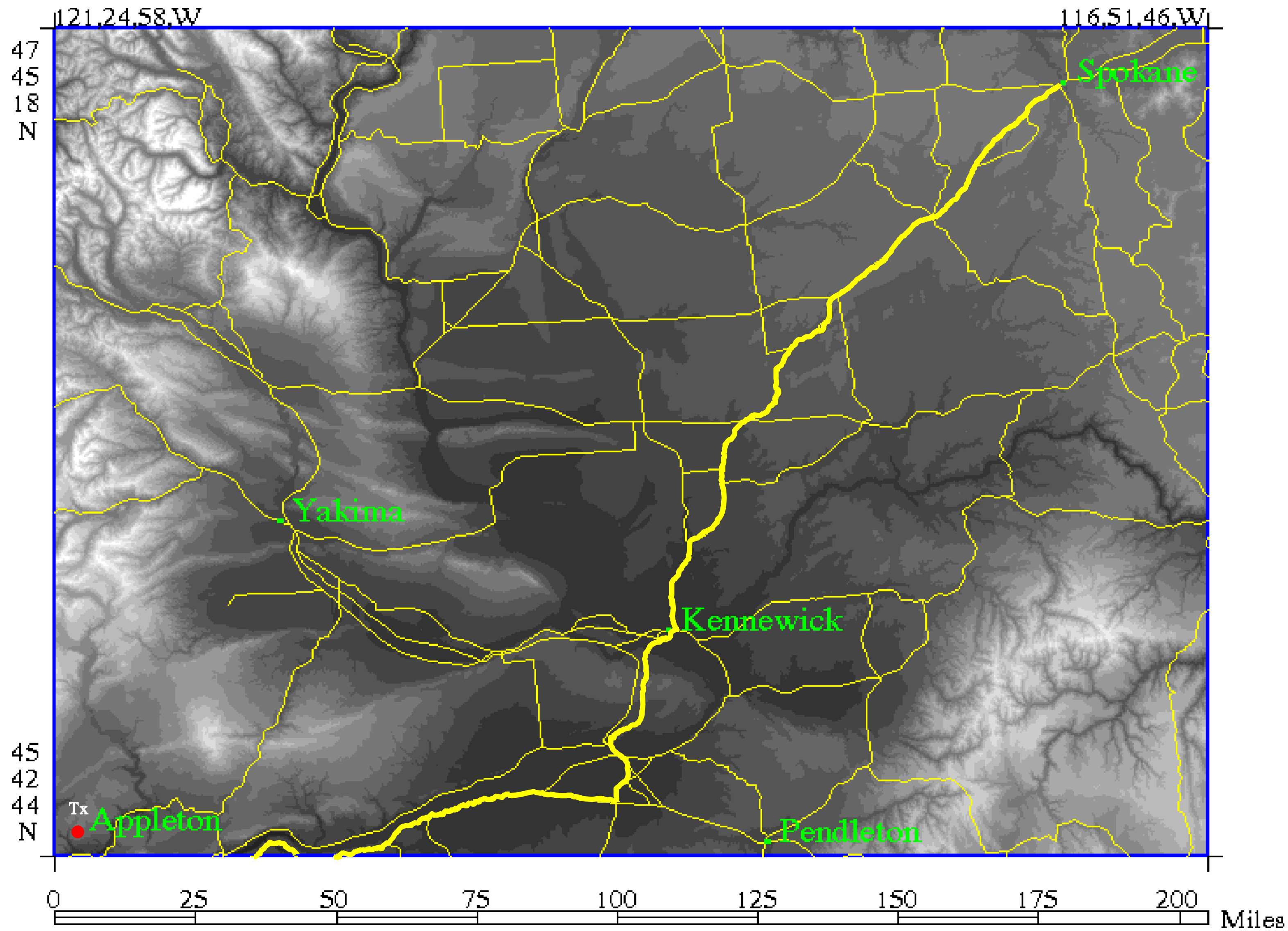

Figure 15. Topography for the route (thick yellow line) between the Appleton GWEN site and Spokane, Washington.

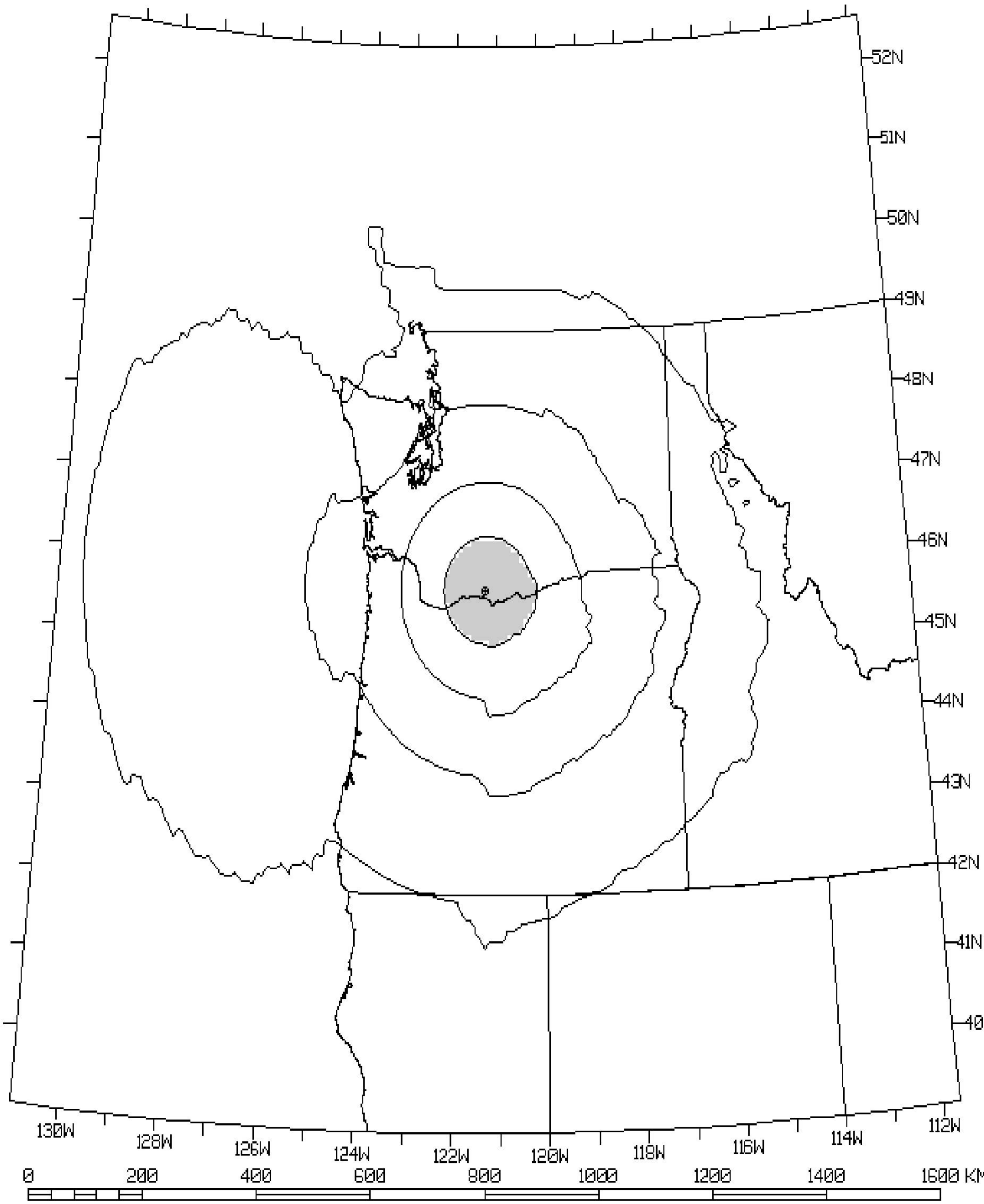

Figure 16. Signal coverage prediction plot for the Appleton GWEN site showing contours for field strengths of 37.5, 50.0, 60.0, and 70.0 dBμV/m.

However, to obtain the measured field strength of approximately 28 dBμV/m at Bellingham (330 km from Appleton), a conductivity of 0.0008 S/m had to be used in the model. This value of conductivity is typical of poor ground, which is often found in mountainous regions. Thus, realistic variations in ground conductivity that are not represented in the database could easily account for the discrepancies between the model and the measurements.

10. SUMMARY

Field strength measurements were conducted to determine the signal coverage generated by a GWEN antenna and a DGPS transmitter used by the U.S. Coast Guard. The measured field strengths at 10 km correspond closely to theoretical expectations based on detailed modeling of the GWEN antenna using an antenna efficiency of approximately 50%, producing a radiated power of 500 W for an input power of 1 kW.

The dependence of field strength with distance from the transmitter is in good agreement with the predictions of propagation models in the absence of irregular terrain. However, in hilly and mountainous terrain, the model tends to predict field strengths that are greater than those that were measured. Some of the smaller discrepancies (on the order of a few dB or less) appear to be due to irregular terrain effects, for example, decreases in field strength when the receiver is in the shadow of a large terrain feature. However, larger discrepancies (as large as 10 dB or more), are presumably due to an incomplete database of ground conductivities in irregular terrain. When using model predictions to plan a nationwide DGPS service, it should be realized that small gaps in coverage that are not predicted by the model may occur, and will have to be dealt with on a case-by-case basis.

11. REFERENCES

[1] "U.S. Air Force Ground Wave Emergency Network final operational capability: final environmental impact statement," Department of Air Force Report, Vol 1, Sep. 1987.

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[3] E. Haakinson, S. Rothschild, and B. Bedford, "MF broadcasting system performance model," NTIA Report 88-237, Aug. 1988.